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What is Forest Restoration ?

John A. Stanturf, Project Leader

USDA Forest Service, Athens, Georgia USA

Introduction

Humans have influenced landscapes and forests for millions of years, constrained only by the sophistication of their technology and the abundance of resources available. Influences on forested landscapes have included hunting, pasturing and grazing livestock, harvesting fuelwood and timber, using or suppressing fire, and introducing new species. The ability of humans to affect forest ecosystems increased dramatically after the Industrial Revolution as construction intensified of roads, dams and levees, and mines. Over large areas, native forests were first exploited and then brought under management and the switch from biomass to fossil fuels changed traditional forest management in many countries. Emissions from industrial sources, electric utilities, residential heating, and transportation affect forests directly by pollution and acid deposition and indirectly through climate change. Today's forests are the result of all these anthropogenic disturbances, along with climatic change and species migration into postglacial landscapes.

Forest restoration seeks to reverse the negative effects of human activities (Stanturf and Madsen 2005). The complexity of ecosystems, their current state and past land-use, and the human context of culture, economics, and governance largely determine the specific motivations for restoration in a society. In most countries, restoration is undertaken within the policy framework of increasing sustainability by enlarging the area of specific ecosystems, enhancing biodiversity or repairing ecosystem functions, although specific goals, techniques, and incentives vary. Specific objectives for restored forests in developed countries commonly include timber, wildlife habitat for game species, or aesthetics. Increasingly, other objectives are considered, including carbon sequestration, biological diversity, non-game mammals and birds, endangered animals and plants, protection of water quality and aquatic resources, and recreation. In developing countries, forest restoration is linked to alleviating poverty and rural development (Lamb et al. 2005).

The term restoration is used indiscriminately and it is difficult to define in a way that encompasses all situations found in the literature and in practice. Generally, restoration is seen as symmetric with degradation: an undisturbed forest in a natural or historical condition can be degraded, and a degraded forest can be restored to that natural or historical condition. Reality is more complicated and the fully restored state is probably unattainable (Cairns 1986; Stanturf and Madsen 2002). Ecological restoration "is an intentional activity that initiates or accelerates recovery of an ecosystem with respect to its health, integrity and sustainability" (Society for Ecological Restoration 2002). For many practitioners, ecological restoration means a return to a non-disturbed natural condition guided by a reference site. This notion of naturalness as a basis for restoration has been challenged by practitioners within the restoration ecology community and other resource professionals. At issue is whether naturalness represents a scientifically defensible concept or is simply a statement of a preference for one kind of ecosystem over another. Terminology, however, is not merely an academic issue; definitions related to forestry and restoration are used under several international conventions such as climate change and biodiversity where distinctions and nuance have important policy implications (FAO 2002). The objectives of this paper are to offer a conceptual framework for defining forest restoration and to highlight major issues requiring research in multiple social contexts.

What Is Restoration?

Forest condition is dynamic, subject to natural developmental processes. Degradation results from changes to forest structure or function that lowers its productive capacity (FAO 2002), including limited biodiversity. Degradation is not synonymous with disturbance; disturbance becomes degradation, however, when it crosses a threshold beyond the natural resilience of a forest type. The simplest conceptualization of the relationship between degradation and recovery processes is to place a forest on a continuum from natural to degraded (Bradshaw 1997; Harrington 1999). Levels of state factors such as biomass or biodiversity in a forest subjected to degradation follow a linear trajectory. At any point along the trajectory, recovery toward a natural forest can be initiated once the stress or disturbance abates. Intervention can facilitate recovery from disturbance or degradation. For convenience, intervention can be divided into three levels of increasing effort: self-renewal, rehabilitation, or reconstruction/reclamation (Stanturf et al. 2001). In the self-renewal phase, resistance and resilience mechanisms maintain or return the forest more or less to its original state, without human intervention, in a relatively short time. Sustainably managed forests rely on self-renewal processes, for example, naturally regenerated forests managed for timber. Intervention at this stage will be to ensure that composition and structure meet management objectives. Plantations of native species can be within the scope of self renewal, where intervention (reforestation) is undertaken to control species and stocking.

At intermediate levels of disturbance, beyond the self-renewal phase, degradation occurs. If a forest is degraded but remains in forest land-use, meaning it is not deforested, it can be rehabilitated to a forest condition that is within the range of self-renewal mechanisms.

Recovery to a more natural forest will take longer, but the time required can be shortened by human intervention. Rehabilitation by reforestation of forests consumed by wildfire is an example. In the most degraded state, forest cover is removed and the land is converted to another use: this is deforestation (FAO 2002). A forest degraded by acute air pollution may be deforested to a non-forest condition and the land becomes wasteland. In the most degraded conditions, after the pollution or other land-use ceases, the forest may recover to a natural forest condition in a century or longer. The recovery period may be shorter, possibly decades, with human intervention (reconstruction or reclamation). In this paper, restoration encompasses all interventions into degraded forests, those stands disturbed beyond the range of self-renewal processes. Rehabilitation refers to restoration of degraded forests; reconstruction and reclamation encompass restoration of forests from non-forest land-uses.

The dynamic relationship between processes degrading and restoring forests is more easily understood if considered in light of two dimensions, changes in land cover, land-use, or both (Stanturf and Madsen 2002; Stanturf 2005). Taking as the starting point the undisturbed, idealized natural mature forest (Westhoff 1983; Goudie 1986), then, conversions to other landuse such as agriculture (cultural landscape) or pasture (semi-natural landscape) are through deforestation. Relatively frequent but moderate disturbance (plowing, herbicides, grazing) maintains the non-forest cover. Similarly, a change in both land cover and land-use occurs when forests are removed and the land is converted to urban areas, flooded by dams, or removed along with topsoil and overburden in mining and extractive activities. Such drastic degradation involves deforestation, usually accompanied by ongoing disturbance. The non-forest cover is maintained more or less permanently by structures, more so than by cultural activities. Agricultural land can also be converted to urban uses.

Harvesting a mature forest in a sustainable manner is a change of land cover but not land-use (FAO 2002). A new, young forest will result from natural regeneration or by reforestation. Unsustainable harvesting without securing adequate regeneration, however, may degrade stand structure or diversity. Outbreaks of insects or diseases (especially exotic species), fire suppression and disruption of natural fire regimes, invasion by aggressive exotic plants, or disasters such as hurricanes or wildfires can degrade forest stands and change attributes of land cover, but these stressors do not change land-use. Chronic low-level pollutant loading may degrade a forest without changing land-use, although heavy loading may deforest an area and change use into wasteland.

Forests are resilient: given sufficient time and the cessation of disturbances, agricultural and urbanized land will revert to forest. Abandonment and reversion to forests, although secondary, semi-natural, or degraded forest types, will be on a time scale of a few decades to centuries as existing forests expand into non-forest areas, or natural invasion occurs. Human intervention, however, can accelerate the reversion process (Ferris-Kaan 1995). Reconstructing forests through afforestation of agricultural land may consist of simply planting trees, although more intensive techniques are available (Stanturf et al. 2001). Reclamation of urbanized land usually requires extensive modification, including stabilization of spoil banks or removal of water control structures, followed by tree planting. Because severe site degradation may limit the possibility of restoring to natural forest condition, reclamation is sometimes called replacement (Bradshaw 1997).

The dualistic notion of degradation and restoration as opposing trajectories of forest development leads to an understanding of restoration in a broader context than ecological restoration (SER 2002). In this view, the restored forest that results from reconstruction, reclamation, or rehabilitation may never recreate the original state for all functions (Cairns 1986; Bradshaw 1997; Harrington 1999). Any endpoint within the natural range of managed forests where self-renewal processes operate is acceptable as restoration. Thus, restoration to an early seral stage would be acceptable for a forest that is likely to attain a more complex structure through typical stand dynamics. How quickly the forest moves to the self-renewal phase is a function of forest type, site resources, and the amount invested to overcome the degraded conditions. This model offers a broader context for restoration on private land; landowners with management objectives other than preservation are able to contribute to ecosystem restoration (Farrell et al. 2000; Stanturf et al. 2001).

Restoring Natural Disturbance Regimes

Because of the dynamic nature of forest ecosystems, even without anthropogenic disturbances, it is very difficult to say what would be a natural forest in a given place and time. Nevertheless, there is a recurring theme in the literature of returning forests to more natural conditions and using more nature-based silviculture to accomplish that goal by restoring natural disturbance regimes or using silvicultural techniques that mimic natural disturbances. Understanding the effects of past disturbances and the likelihood of future disturbances is critical to designing appropriate restoration techniques, but disturbance ecologists typically focus only on natural disturbance regimes, eschewing human-caused degradation, ignoring that forests today are human-dominated systems (Noble and Dirzo 1997). Disturbances can operate at multiple spatial (coarse and fine) and temporal scales (frequency or recurrence interval). In many countries, forests are fragmented and rarely are large areas available where coarse-scale disturbances such as wildfire can be tolerated. Forests that are blown down by severe winds, or killed by insect and disease outbreaks, frequently are salvage logged, because of their economic value. These realities pose several challenges for incorporating natural disturbances into restoration and have led to much discussion of "natural" stand structure. The old steady-state paradigm of forest succession to a stable climax led many ecologists to equate complex structure with old forests (O'Hara and Waring 2005) and for some to prefer uneven-aged management over even-aged management because it led to more "natural" forests. In the fortunate instance of large areas of contiguous forest under a single or a few owners, it is possible to restore to a diversity of stand structures on the landscape in roughly the same proportions as occurred historically with little human influence (if that is known), that is to say, under mostly natural disturbance regimes. In populated regions, however, nature-based silviculture that emphasizes restoring complex stand structures stresses the positive aspects of structural diversity in terms of stand stability and biodiversity.

Measuring Success

Restoration will succeed over the long-term if activities are framed in an economic perspective, with distinct, measurable objectives. Because no markets exist for most of the ecological outcomes from restoration, policymakers have no easy criteria for deciding optimum levels of restoration. There is a further spatial dimension to restoration that complicates allocation decisions. For example, within a degraded watershed, restoring some areas will produce a higher level of ecological benefit than others, given the same level of restoration effort. Often, we assume that restoring stand structure and species composition will restore ecological functions, and take this as our measure of success. This is certainly true for afforestation; a tree plantation functions more like a forest than a cotton field or an eroded hillside (e.g., Lee and Suh 2005). Even in general terms, however, a plantation does not offer the same degree of functioning as a multispecies forest with complex structure. One way to measure success is to evaluate the recovery of ecological processes, focusing on key indicators of ecosystem response in terms of the magnitude and duration of response. Because pools and processes that depend primarily on biological agents may vary from those dependent upon physical agents, responses will be variable and evaluation of restoration success will depend upon the choice of the key indicator. Restoration of biogeochemical processes has been proposed as a way to evaluate success (Vose et al. 2005), but it is difficult, because these processes operate at multiple temporal and spatial scales. By focusing on emergent properties of ecosystem processes, such as the budget of nitrogen, an important nutrient, the task is made manageable. Nitrogen pools and processes are sensitive to disturbance and restoration, and often restoring nitrogen pools and processes is a specific restoration objective.

Landscape Restoration

Restoration ecology is an emerging science that developed out of restoration projects at specific sites. Techniques and principles developed from small-scale restoration projects are beginning to emerge but they may not be applicable to the large areas requiring restoration, for example after years of agricultural land use, fire suppression, or following natural disasters (i.e., extreme disturbance events). Because restoration requires ongoing management, the silviculturist plays an important role in bringing to bear time-tested techniques to shape the development trajectory of a stand toward the desired condition, and to maintain the restored ecosystem. The challenge for restoration is immense; large areas of forest and non-forest must be restored to sustainable working forests or to preservation areas. The task requires more imagination and creativity than applying a blanket prescription across an entire landscape, however well that prescription may work. Thus, there is increasing recognition that restoration at the landscape scale requires a different approach than is taken at the stand scale (2005).

Conclusion

Understanding the dynamism of forest stands is critical to identifying appropriate operations for restoration. Oliver and O'Hara (2005) reviewed the changing concepts of forest ecology and how they have been applied to management and conservation. They describe the shift from viewing forest ecosystems as closed, steady-state systems with predictable development patterns to the present view of open systems that operate opportunistically, with multiple developmental pathways following disturbance. To be successful, restorationists must adopt this dynamic view of forests. To be effective, restorationists will have to educate the non-technical restoration enthusiasts as well as the general public in this new paradigm. Although it would be easy to conclude that there is no scientific basis for restoring natural forests because humans and climate change have so drastically changed the whole biosphere, such choices are necessary in a restoration program and the rationale for the choice must be conveyed to the public. The task for the restoration scientist is to interpret the scattered scientifically based knowledge of forest history, stand development, and natural processes, and combine it with practical experience to design objectives that improve sustainability and meet current social preferences for forests that appear "natural."

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